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"THE AVAILABILITY OF ADVANCED FOREIGN ENERGY CONVERSION
AND CONSERVATION TECHNOLOGY FOR USE IN THE UNITED STATES"

BIENNIAL REPORT

MASTER

TO THE U. S. DEPARTMENT OF ENERGY
IN ACCORDANCE WITH CONTRACT #EY-76-C-03-2079

BY

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CHAPTER I INTRODUCTION

This investigation has been carried on for over 2-1/2 years. It has covered advanced energy work in Australia, Japan, the Middle East, Europe, Scandinavia and the United Kingdom.

It has involved literature searches; scores of meetings with Government Officials in charge of energy R&D throughout the World; more than 100 on-site meetings in overseas centers of R&D in energy conversion; hundreds of one-to-one meetings, and scores of conferences with ERDA/DOE Officials in the United States, in which results of the overseas investigations were covered.

It is obviously impossible to repeat all of this data (which has been reported as the work progressed) in this Biennial Report.

The twelve formal progress reports are therefore incorporated in this Biennial Report by reference.

This Biennial Report will then be devoted to Task IV as specified in the current contract as, "Final Evaluation Review and Recommendations."

CHAPTER II
SCOPE OF THE WORK

The scope of the work for this report is clearly set forth in Task IV of the modification #A003 to contract #EY-76-C-05-5085.

Task IV: Final Evaluation, Review and Recommendations:

"Review and evaluate all the field data, and prepare a final report, with recommendations for DOE. This report will define areas where foreign work is ready to be implemented by U.S., areas where U.S. work might be dropped since foreign R&D is more advanced, areas where foreign R&D indicate sufficient promise for the U.S. to initiate work in, areas where cooperative R&D ventures or licensing agreements might prove beneficial, etc."

Special note should be taken of two factors which affect this Biennial Report.

1. While the technologies in the contract are very broadly defined with such terms as, "the areas of controls and process efficiency materials fabrication components", as well as "thermodynamics; heat transfer combustion; alternate fuels; heat utilization and planning and analysis"; repeated conferences throughout the 30 months consumed in this contract were held with the Project Managers at ERDA/DOE. In each case, the broad fields, mentioned above, were narrowed to specific types of technology under consideration in DOE programs. For example, Fluidized Bed Heat Exchangers, Coal-Oil Mixture, and Stirling Engines to name a few.
2. As the mission of the Conservation Research and Technology Division of ERDA was changed, with the creation of the Power Systems Division in the Fossil Fuels Section of DOE, the directives of the Project Managers for

prioritizing various items in the Galaxy contract also changed.

This meant that earlier priorities were changed drastically to fit the new missions.

No work was abandoned in mid-stream. However, a review of the Quarterly Reports shows the sweep of these changes.

Therefore, some of the areas of overseas research and resulting recommendations called for in Task IV, refer to work which has now been moved to other Divisions within DOE. It may be of interest to these Project Managers as they continue on their missions.

It should also be noted that additional priority assignments made in the final days of this contract could not be carried out, pending authorization to continue.

CHAPTER III
GENERAL COMMENTS

Galaxy has been in the international transfer of technology field for two decades.

As far back as 1962, Galaxy prepared a report, "Research in American Industry." This report pointed out that research as a percentage of the gross national product, had been falling.

The report projected, (if the trend continued), that by the mid 1970's, the U.S.A. might be losing its leadership in technology.

Unfortunately, within the past few months, this grim projection appears to be verified. Several periodicals such as McGraw Hill's, "Business Week" state, "America's vaunted technological superiority of the 1950's and '60's is vanishing...." That message and its implications for the overall health of the U.S. economy is starting to get through. The matter has now come to such a critical nature that the White House itself has ordered a study. Stuart E. Eizenstat, the White House Domestic

Policy Adviser, in a recent memo outlining the review's intent, said, "Federal policy affecting industrial R&D and innovations, must be carefully reconsidered."

Presidential Science Adviser, Frank Press, says, "We badly need some new directions." Mr. Press continues, "We also ought to find out what's going on abroad."

In the research that is now underway, some of the projections which Galaxy made 16 years ago, are beginning to be revealed in the changing character of industrial research.

The amount of basic research that industry performs for instance has dropped in the most recent figures available from a 38% of the national total in 1956 to just 16%.

Herbert Hollomon, Director of Center for Policy Alternatives at the Massachusetts Institute of Technology, and formerly a leading U.S. Government R&D Official, states, "A reason the U.S. is losing its leadership is that we are arrogant. We have NIH (not invented here) complex, at the very time the majority of the tech-

nological advances are bound to come from outside the U.S. As much as 2/3 of all R&D is now conducted by foreign laboratories. It should be of no surprise that they are taking the lead in such technologies as textile machinery and steel production." Mr. Hollomon concludes, "I believe other nations better understand that innovation processes are important."

Galaxy notes that the discrepancies between U.S. and overseas advanced R&D expenditures are greater than the figures themselves show. Approximately half of all R&D expenditures in the U.S. are for military hardware or defense related projects. While there is undoubtedly some 'fallouts' from such R&D, it is nowhere near as productive for technological advance as let us say, the European savings of energy in cement production; or the Japanese clear superiority in steel, or the consumer goods electronics fields. As an example of the latter, there are five video-tape machines on the U.S. market at the present time - none of them produced in the U.S.

Therefore, it is important to face up to these facts which are now becoming so critical. The Germans now flatly state to Galaxy, "as far as we are concerned the U.S. is an LDC, in regard to advanced technology." This is a bitter pill to swallow, but we should take our medicine and get on with the business of rebuilding our leadership.

This is not a problem that can be cured by one dramatic stroke. It will take at least five years to a decade. But it is important that we begin.

In making this assignment to Galaxy in 1976, DOE recognized these points. The specific priorities assigned to the Galaxy searches showed the Technical Project Managers were aware of advanced work overseas.

Galaxy's Quarterly Reports from Japan, Germany, France, the Scandinavian countries, the U.K., and even Israel clearly highlighted the advanced nature of some specific technologies. The reports also showed the areas where no advanced work was being done overseas. This

enabled Technical Project Managers to proceed with the knowledge that we were not re-inventing the wheel. This was pursuant to the concern expressed by Congress in 1975, that funds supplied for energy R&D not be dissipated in duplicating work already done overseas. Thus, either a positive or negative answer in specific overseas innovations was of use to the Technical Project Managers in planning their work.

There are, of course many areas where the U.S.A. work is more advanced than overseas R&D. In some cases, careful investigation revealed that overseas advances were based on U.S.A. developments.

CHAPTER IV GEOGRAPHIC REPORT

In order to provide a quick review of overseas work by major countries, a brief overview of findings on a geographic basis is helpful. The comments are Galaxy's headquarters staff, after reviewing the reports of the Field Officers.

Australia:

The Australia search revealed mostly derivative technology. They claim to be ahead of anybody else in commercialized hot deboning and well advanced in drip irrigation and some aspects of wood combustion. However, Galaxy found that the U.K. was far ahead in a hot deboning research project; Israel in applied drip irrigation, and Scandinavia in wood combustion.

Japan:

The Galaxy office in Japan (entirely staffed with Japanese) originally reported the Japanese Government stated that most Japanese technology was coming from abroad.

This was carefully investigated by Galaxy's headquarters staff during interviews with leaders in Japanese Government and industry in Tokyo. These interviews revealed, Japanese steel and cement industries were far more energy efficient than their U.S.A. counterparts. Companies such as IHI and Mitsubishi Heavy Industries have some good residual oil fired turbines, bottoming Rankine cycle work, and advanced heat transfer technology. There is advanced work in combustion of industrial wastes, as well as coal oil mixtures, for both steam and diesel use. Advanced high purity silicon carbide and nitride powders are available in Japan, which may be useful in high temperature hostile environment uses.

Israel:

Israel has the most advanced operational drip irrigation system, as well as ongoing research on new drip irrigation developments, and use of brackish waters for irrigation with resultant energy savings. Israeli universities and development agencies have a great deal of computer and laboratory work on cycles, turbines, heat exchangers, combustion., etc., but pilot plant stage or commercialized developments are largely lacking.

Switzerland:

The Swiss "invented everything". Sulzer, Brown Boveri and numerous other private sector firms have a good many patents and licenses in combustion, gas turbines, and advanced heat transfer and recovery to prove it. Further developments of these Swiss basic patents in Germany, Sweden and the U.K. substantiate these claims.

Germany:

The Germans' work in topping and bottoming cycles; in waste heat recovery and cogeneration; in recovery and use of methane from coal beds; in advanced combustion technologies, and in numerous other coal based energy sources, shows what a highly developed petroleum short nation must do in order to meet their problems. Also, the ceramic work at Max Planck Institute and the industrial application of the priority technologies are well advanced.

France:

In France, while the greatest emphasis is in nuclear work, and generally outside the scope of the Galaxy contract, some work on combustion and cogeneration, coal and methane utilization, as well as advanced cycles using cryogenic energy from LNG gasification is worthy of note.

Italy:

Because of the extremely unstable political and economic conditions in Italy, only the gas turbine work of Fiat, as well as some dry tower plastic tube heat exchangers was examined.

Denmark & the Netherlands:

Denmark and the Netherlands proved minor, but some interesting work on diesel waste heat recovery, combustion and fluidized bed furnaces is being done. In the Netherlands, high temperature, high capacity fuel cell work was dropped after discovery of the North Sea

gas fields, on the conclusion it cannot reach objectives. However, Norway has provided some excellent data on ceramic coated pistons, and cylinders in diesel engines using some cylinders in working seagoing diesels as test beds.

Austria:

In Austria, the work of Professor Gilli was noted, as well as some combustion efficiency in the state owned steel plants.

Sweden:

Sweden was, as anticipated, full of interesting work at University, Government and Industrial levels. Blue flame combustion; heat engines; heat recovery; heat exchangers; heat storage; long distance transmission of low grade heat; large stationary Stirling engines; and energy efficient housing are well advanced. The Swedes are well aware of the usefulness of their work and its energy saving potential.

United Kingdom:

The U.K. proved to have high temperature theoretical heat work, as well as fluidized bed combustion, etc., at Harwell, GEBC and elsewhere. There is also advanced university research at Bristol in hot deboning, advanced development and commercial production of heat exchangers at such firms as Fluid Fire Development. Both in theoretical and applied fields, the U.K. provides many areas for further cooperation, which is now underway.

General:

An investigation such as this could not, of course, cover every obscure scientist working in a small scale specialized laboratory of some otherwise undistinguished institution.

In each case of a priority assignment, Galaxy made preliminary reports. When the Project Managers indicated the preliminary information merited follow-up, the Galaxy field personnel provided indepth reports. In certain cases, Galaxy's headquarters staff visited top Government and corporate officials for follow-up and to arrange for technology transfer where it was desired.

International Agencies:

Galaxy's Washington personnel also worked with the IEA, CCMS, and EC groups in each of the priority fields. These discussions primarily revealed the state of public sector work sustained through the working parties. Because of the intermittent meetings of the working parties, and the distracting influence of the Chairmen for their regular duties, as well as the participation of DOE executives in the international process, no extensive reporting was done on these agencies or officials on the basis of their international positions.

CHAPTER V RECOMMENDATIONS

The chapter titled, 'General Comments', outlined some of the problems now facing energy R&D in the U.S.A.

Subsequent chapters cover and define the areas where foreign work is ready to be implemented in the U.S.; areas where foreign work is more advanced, etc. This chapter deals with general recommendations called for in the contract.

Many nations are substantially in advance of the U.S. in energy utilization and conservation of petroleum fields. Outstanding examples are the dry cement process with almost a 50% savings in energy; the steel process in Japan with a 25% energy saving; the use of reject heat in Sweden; development of more effective heat exchanger technology in the U.K.; even the energy efficient drip irrigation technology in Israel. Not included are the advances on magnetohydrodynamics in Russia.

This is not to state that the U.S. is making no progress. It is to state that we have much catching up to do, and can benefit from the advanced work elsewhere.

Separate sections later in this report evaluate field data from the various priority technologies selected by ERDA/DOE, where the U.S. is apparently in advance of that in the U.S., and some of the areas where foreign R&D indicates sufficient promise for the U.S. to consider cooperative R&D ventures or license agreements.

A review of the preliminary and indepth reports shows that in some cases many months elapsed between the preliminary report and the requested follow-up. This reflected the developing DOE program. As the DOE missions change, many of the preliminary reports in the earlier quarterly reports may be the subject of follow up work.

In a substantial number of cases, DOE Technical Managers visited sites selected by Galaxy for eyes on investigation of the advanced work underway.

Despite the problems caused by lack of feedback from various units within DOE, and the long gestation period noted under 'recommendations', this review falls into six categories.

1. Foreign Work Already Transferred:

The most definitive transfer is where DOE has imported overseas hardware for test here - as in the case of the Fluidfire Heat Exchanger; the Japanese Hitachi High Flux Heat Transfer Surface, "Thermoexcel"; Drip Irrigation from Israel, etc.

Perhaps easier to grasp, is the work of Dr. Peter Margen on plastic heat exchangers and long distance transmission of low grade heat with multiple visits back and forth.

2. Transfer of Advanced Researchers:

Bringing overseas advanced researchers to U.S.A. for extended work or shorter seminars here is a valid method of technology transfer. However, quantitative measurements of this method of transfer are very difficult. No quantitative measurement of the impact of Professor Loeb, whose ad-

vanced work on pressure retarded reverse osmosis or Professor Schacter on direct combustion of oil shale is possible for Galaxy, at this stage, although in another 2 years this may be apparent.

3. On-Site Visits by DOE:

In the same way, overseas visits by DOE Program Managers to installations of topping cycles in Germany, or the Norwegian ceramic diesel piston covers and rings, and cylinder liners in Norway provide the best guidance in developing American programs.

4. Negative Reports Clearing Way For R&D Here:

At the opposite extreme are the negative reports. No overseas work could be identified on determination of the dew point of diesel exhausts, in order to design more efficient diesel waste heat recovery systems. This cleared the way for a DOE R&D program in the U.S.A. Similar negative reports on diesel rankine cycles, and in such fields as small steam turbines, led to programs here.

5. In a separate category are the technologies recommended by Galaxy, not anticipated by priority assignments from DOE Project Managers.

The cryogenic energy available from LNG landing and gasification plants in U.S.A. are an example, (reported in detail under "Waste Heat Recovery").

The problem is institutional rather than technical. Galaxy investigated overseas LNG landing plants in France, Japan and elsewhere, where the problems also are institutional rather than technical.

Galaxy recommends serious and continuing attention to LNG-Nuclear plant sitings and use of this inexpensive energy.

6. The area of licensing agreements for transfer of technology is, of course, Galaxy's special field of expertise. Licensing was specifically exempted

from the current Galaxy contract, although we had recommended its inclusion during the original discussions.

During the 30 month period of this contract interest in licensing technology, both incoming and outgoing has vastly increased. Theoreticians in the field abound. Experience in actual licensing is in very short supply. The result is a number of studies, but little practical application.

Admittedly, there are problems concerning the role of DOE, which itself is not the ultimate users. But these problems are soluble. The interest of the DOE, the U.S. Government, the producers and consumers of energy will best be served by vigorous encouragement of this aspect of transfer of technology, particularly in the private sector.

As noted, greater consideration should be given to licensing as a practical method of transfer of advanced technology and an encouragement of R&D. Neglect of this field is to stifle individual and private initiative, and the slowdown of attaining the goals of better use of our energy resources, as well as improving our environment.

Overseas Galaxy finds the public sector eager to secure U.S. funds for further studies and research. But conversely, the private sector, with full knowledge of the Freedom of Information Act here, is skeptical of participating with DOE in any practical developments. This is a problem which deserves more intelligent innovative attention than it is getting, while the U.S. is falling further behind in innovative and effective developments.

Various divisions, sections and offices of DOE are engaged in a number of studies on the transfer of technology. From Galaxy's two decades of international experience in this field, we recommend consideration of

ready, professional, existing avenues for such intellectual exchange and transfer without the need for expensive further research and study.

For example, in the private sector, the Licensing Executives Society (of which Galaxy's Vice President International is a charter member) is composed of over two thousand members whose principal professional activities are devoted to the actual transfer of technology throughout the World and who are responsible for achieving the successful transfer of technology, via sale, licensing, joint venture, etc. of the preponderance of such transactions that have taken place in the world for a number of years.

Its members are professionally trained and capable of handling all of the diverse phases and disciplines covering the patents, legal, technical and economic aspects, as well as the skills necessary to successfully complete such transactions.

Galaxy submits that the time is past for further expensive studies and to get on with induction and transfer of technologies within the sphere of DOE's needs where foreign technology and research is in advance of our own; or conversely, where the U.S. has technology of use overseas, especially in the LDC's.

For the purpose of locating and pinpointing the existence of advanced technology and its various stages of development, we depend first on our overseas offices. We are well aware of the various computer banks, including those sponsored and financed by Governmental departments, as well as universities, technical societies and private sector entrepreneurs. However, in Galaxy's view such road maps should be augmented by employing the research, technically experienced groups basically familiar with private sector industries that are known or reported, or apt to be performing advanced research in the universe of DOE's interests.

In this theater, groups such as L.E.S. with a record of successful licensing negotiations and technology transfer are in a preferred position to elicit non-confidential and sometimes confidential disclosure of data on which DOE decisions can be based.

In view of the rather long gestation period for consideration of overseas technologies, a review or sweep should be made each 18-24 months, with updating of the state-of-the-art in each energy category, so that Project Managers may have available up-to-date data for their decisions.

DOE must find a mechanism by which its various branches, divisions, and sections can be kept abreast of similar work in other units. Often during the two and one half years of the Galaxy contract, we became aware of other units within and contractors to DOE performing similar tasks overseas. Admittedly, with any program as complex and fast moving as DOE, this presents many problems. For example, a section on materials may

be searching for a more heat and corrosive resistant material and go to a gas turbine manufacturer. Another unit, charged with more efficient gas turbines through higher flame chamber temperatures, may also seek the same technologies. Still other units, working on advanced cycles may have similar interests.

Galaxy recommends a computer information program kept reasonably current with DOE's overseas work and interests to save time, effort and funds.

CHAPTER VI
EVALUATION OF FIELD DATA

Task IV of the assignment by DOE requested Galaxy to, "Review and evaluate all field data" and to "define areas where foreign work is ready to be implemented by U.S.; areas where U.S. work might be dropped since foreign R&D is more advanced; areas where foreign R&D indicate sufficient promise for the U.S. to initiate work in; areas where cooperative R&D ventures or licensing agreements might prove beneficial, etc."

The specific technologies to be investigated by Galaxy were set forth in Tasks I and V of the contract as follows:

Task I:

- A. Waste Heat Utilization.
- B. Advanced Cycles.
- C. Component Reliability and Efficiency.
- D. Heat Transfer.
- E. Combustion and Materials.

Task V:

- A. Controls and Process Efficiency.
- B. Materials and Fabrication.
- C. Components and Heat Engines.
- D. Thermodynamics and Heat Transfer.
- E. Fuel Cells.
- F. Combustion and Alternate Fuels.
- G. Heat Utilization, Planning and Analysis.

In this chapter, the foreign technology is briefly identified within the areas set forth in Tasks I and V, and under these, the categories set forth in Task IV. For more complete data on each technology, please refer to the appropriate quarterly progress report. All twelve formal progress reports are included in this final report by reference.

These assignments were carried out as directed. However, there is some overlapping in the various categories. For example, combustion investigations involved IC and continuous combustion; diesel engines; component reliability; coal oil mixtures; fuel cells; agricultural wastes; etc. Therefore, for clarity in this Biennial

Report, the various technologies have been grouped as follows:

1. Advanced Cycles, Components, Heat Engines, and Fuel Cells.
2. Heat Transfer and Thermodynamics.
3. Waste Heat Utilization, Planning and Analysis.
4. Combustion, Alternate Fuels, Materials and Fabrication.
5. Controls and Process Efficiency.

1. Advanced Cycles, Components, Heat Engines
And Fuel Cells.

A. Rankine Bottoming Cycles:

This assignment objective was carefully defined as, "a small closed Rankine Bottoming Cycle engine whose capital cost is \$300 to \$400^{*} per installed KW", with the "primary target - Japanese IHI Bottoming Cycle...."

(See reports of July 1976 - et seq)

Our Japanese office reported in 1976, "IHI are now selling the equipment which has the standard specification of 490 KW power generation in using 3 KG/CM² saturated steam as heat source and industrial water for cooling it....\$510 per KW, considerably higher than \$300 to \$400 per KW....this price per KW does not vary much by enlarging equipment size.... the heat efficiency in this case is about 10%."

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*All prices of overseas work in this entire report are quoted in terms of the value of the dollar against foreign currencies at the time of the specific report.

This report went on to specify that the IHI present equipment cannot tolerate either gas turbine or diesel waste heat due to limitations of the Freon 11 as fluid.

Galaxy then sent a senior researcher to talk with senior IHI Officials in Japan.

A three hour discussion revealed that if 5,000 KW was classified as small "the price drops to \$350 per KW installed, based on 340° F waste heat stream, and 85° F cooling waters."

While the present Freon 11 machines are limited by Freon 11, IHI stated that when Freon 12 is used, a capacity of 10,000 KW is possible. NH_3 and Butane also can be used as a working medium.

Galaxy recommended this technology to ERDA/DOE.

Subsequently, this technology was brought to U.S.A. by Allied Chemical, is installed and working.

In other nations there is much interest in Rankine Cycles. Many computer analysis programs appear to be available, but tested machines are notable for their absence. There were no Rankine Cycles based on diesel or gas turbines due to absence of suitable fluids or heat exchangers.

Ormatt in Israel has a Freon based "Energy Converter", originally conceived to use solar energy. It didn't work out, and is now fired by a gas flame.

Other areas under investigation yielded results all the way from "no significant work in Australia", through many computer simulation programs, to feasibility studies and isolated individual installations in Germany, the Netherlands, Denmark and Sweden.

All individuals and institutions agreed upon the necessity for "organic fluids, non toxic and not expensive, which can stand stack temperatures." All agreed they knew of no such fluids now, or advanced work on them.

Helium Topping Cycles:

The closed cycle gas turbine first proposed by C. Keller in 1939, resulted in a number of installations in Europe and Japan.

Galaxy's Swiss office, which has kept in touch with Dr. Keller, reported the Escher-Weiss patents in 1976 and the advantages of the total energy concept.

In 1977, a discussion by Galaxy's field personnel was held with GHH Sterkrade, the German contractor which had made the major installations. The technical literature was transmitted to DOE.

In 1978 Galaxy arranged for an on site inspection of the 50 MW Helium Turbine at Oberhausen, which uses methane from coal mines as well as bituminous coal.

Galaxy has not been informed on DOE's decision on transfer of this technology.

B. Stirling Engines:

The primary target assigned was "co-operation with Japan on Stirling Engine Development." (See reports of June 1976 et seq).

Galaxy held extended discussions with the appropriate Japanese Ministries, Universities and Industrial organizations.

They confirmed that Phillips has "all-lateral" Japanese patents, Japanese firms can't proceed unless the Phillips patent terminates, or the Japanese Government allows a great budget for development of this technology. For this reason, they explained, compared to the gas turbine, the Stirling Engine is "newborn in Japan," and therefore the "technology is not in advance of the U.S.A."

However, the continued investigation revealed that at Malmo, Sweden, United Stirling, a subsidiary of Kockums Shipyards has a substantive technology to offer.

Galaxy sent a senior staff member to Malmo in 1976 and again in 1977. (See report of June 1977).

President Wannberger of United Stirling told Galaxy that while United Stirling was part of Ford-Phillips-MAN combine on Stirlings of automotive size and he was able to offer that technology, United Stirling has retained the right to the larger stationary and marine sized technologies, and was ready, willing and able to enter into license and development contracts on this without reference to Ford-Phillips-MAN.

Mr. Wannberger however, confirmed they had then currently suspended the work on the single cylinder Stirling development which will be necessary for the larger stationary and marine installations.

In a second visit in June 1977, President Wannberger stated, "While their program in the large (1 megawatt and multiples thereof) Stirling stationary unit was progressing, there was a lack of funds for more rapid work on this, since their major energies are going into production of the automotive units. However, United Stirling states they can develop a prototype of the larger unit in 3-5 years, for a total cost of \$3 to \$5 million dollars. They are willing to fund half of the necessary investment."

As part of the United Stirling development work, they have made considerable progress in ceramic heat exchangers, which are treated elsewhere in this report.

Also, they are working with coal fired and solar fluidized bed heat sources, heat pipes, etc.

This was the most advanced Stirling work found, although interest and paper projects were found in many places.

Galaxy recommended the United Stirling technology on large stationary Stirling Engines as being in advance of the art in U.S.A. Galaxy has been pleased to learn that an American Contractor to DOE has now entered into an agreement with United Stirling for further development of this technology, with the aid of DOE.

C. Gas Turbines:

The objective was clearly defined (see report of June 1976) a technology of 2300° F in combustion chamber and 7500° BTU per K.W.H.

The work in Japan, Australia and Israel yielded nothing to match the criteria. However, a Japanese Mitsubishi Turbine using C-grade heavy oil in 5000 KW turbines appeared of interest.

In Europe, Sulzer, BBC, Stahl Laval, Siemens, A.E.G. Althorn and Fiat were primary targets.

The new technology for gas turbines developed by Mitsubishi Heavy Industries first described as:

- a. "Is used for gas turbine with a capacity of more than 5,000 KW. The C-grade oil contains sulfur, vanadium, sodium,

etc., and its flow characteristic is not good. The corrosion of turbine blade by the impurities in the high temperature combustion gas is prevented by:

1. "Purification technology of the C-fuel oil,
2. "Certain additive is added to the fuel so that S, Va, Na do not react with the metals constituting gas turbine.
3. "The surface of turbine blade is coated to avoid adhering of impurities,

"The temperature in the combustion chamber is about 900°C , but they are trying to raise it up to 1000°C .

b. "Mitsubishi has also developed "Low
Nox combustion technology" to be
applied to the combustion chamber."
Mitsubishi finally claims this tech-
nology is higher than that of world
level.

The details were furnished to ERDA/DOE
in 1976.

Dr. Adler in Israel has a computer simu-
lation, which analyzes all inputs, outputs,
state of each stage, reveals all weak
spots, simulates the control system, etc.,
and may be run backwards to simulate com-
pressors.

This was offered to ERDA/DOE in 1977 and
a DOE Official made a visit to the uni-
versity where the work was done in 1977.

Stahl Laval of Sweden has a new FT 50 turbine with 2200°F in the Flame Chamber with hot spots up to 2500°F. Stahl Laval uses cooled vanes with a trailing edge temperature of 1500°F. The base load is 1.04 MW, and the heat rate 9550 BTU/KWH, and cost is claimed at \$100.00.

Sulzer of Switzerland has developed a fuel purifying equipment to enable turbines to work with heavy fuel oils. It is a two-stage process. Vanadium is removed by means of an inhibitor; sodium and calcium are in the form of salt water and are removed by a centrifuge.

Two systems are being marketed; one is built by Alfa Laval of Sweden; the other by Petrolite of Hamburg in Germany.

Alfa Laval's unit costs \$300,000 for a 3500 KW turbine.

The details of these systems were furnished to ERDA/DOE.

Galaxy also investigated the Norwegian
Konigsberg Radial Turbine in 1977, which
claims 3000⁰ F in the flame chamber.

Galaxy submitted literature concerning
this development in April 1977, with the
offer of Konigsberg to develop this work
further.

D. Components:

A variety of technologies were targeted by Project Managers. Only a few are briefly reviewed here.

1. Ceramic Materials:

The energy absorbing micro-crack work of Dr. Claussen of the Max Planck Institute, leading towards high strength ceramics was reported in 1976. Early testing proved that cracks at right angles would prevent the growth of dangerous cracks and weakening of the material.

This work was recommended to DOE for follow-up.

This work is currently being followed by U.S.A. companies. Advanced Materials Engineering Ltd. of the U.K., has also followed this work.

Curiously, the Japanese, who have been in the ceramics business for centuries report they are just starting research. IHI has done some experimental work on ceramic blades about 100 millimeters long, but report no industrial installations.

The Toyota-Nissan program is directed towards a fuel consumption of 200 grams per hp/hr. for trucks in competition with diesel and 180-190 grams per hp/hr, and a price of \$17.00 per hp for truck engines, and \$3.40 per hp for automobile engines.

Galaxy found the Norwegians had made important advances in the use of ceramic coatings. (See report of May 13, 1977 et seq).

So far, they have coated piston tops on Sulzer, and Burmeister and Wain large diesels with a piston diameter of "somewhat

less than a meter". By coating one or two pistons in a multi-cylinder engine, they are able to get direct comparisons on use. With these ceramic coated piston tops, they are able to get 30,000 hours use from the coated-top pistons, as against 12,000 hours with the uncoated pistons - a ratio of 2-1/2 times. Essentially, those ceramic tops reduce corrosion in direct comparison with other pistons. They now estimate that they will be able to increase the piston life to 40,000 hours.

They are also conducting tests with coating the valves and the cylinder domes, as well as coating rings and piston grooves. This enables work to be observed in an isolated fashion. These tests are being done in actual marine installations on ships in normal commercial service.

They report that they are having no problems with lubrication, and in fact the ceramics are improving the lubrication.

They are not interested in higher temperatures in the cylinder - just longer life.

They are beginning to experiment with these same types of coatings on gas turbine blades. They believe their work is in advance of that in other countries.

Galaxy also transmitted to DOE a number of technical papers covering this work.

These papers also show Dr. Ingard Kvernes is also working on ceramic coating for turbine blades, looking toward using untreated, or lightly treated North Sea crude oil in the flame chamber.

As a result of these reports, DOE sent a specialist to Norway to follow-up on this work, providing for direct transfer of the technology for use in the DOE program.

In Sweden, United Stirling has some interesting ceramic heat exchangers in connection with its Stirling Engines.
(previously reported)

In other European countries there is considerable interest, research and talk about ceramics, but we have mentioned the top items found here, with the possible exception of Brown Boveri in Switzerland. Their research department told Galaxy they are doing advanced ceramic work which is still designated as "secret". In 1978 Brown Boveri announced the first of this type of high temperature heat exchanger was available for use, but limited as to pressure differential.

These developments are recommended for further follow-up where DOE Officials have not yet visited test or commercial installations.

E. Heat Engines:

Rankine Cycles, turbines and Stirling Engines are already covered. Two additional technologies were assigned to Galaxy.

1. Industrial Heat Pumps:

The priority assignment was to search for a foreign technology to raise low grade waste heat to 400^oF or 500^oF at a COP of 3.5 or better. (See June 1976 Report et seq)

These criteria were discussed with universities, Government Agencies, Laboratories, and equipment manufacturers and users in Japan, Australia, Israel, Switzerland, Germany, the Netherlands, the Scandinavian countries and the U.K.

Professor Gilli, who headed the IEA Heat Pump Committee, stated the goal was un-

realistic, and should be revised toward heat recovery from 90°F to 130°F streams and lifting these to 250°F, but cites the problems are compressor design and limitations of fluids available.

Galaxy's further investigation adds lubricants and seals as limitations.

However, continued search finally led to H. Schibby of Svenska Roto Machinen A.B. of Sweden. SRM claims an industrial heat pump delivering in the 250°F range, using screw type compressors. Galaxy submitted extensive material on this work in 1976 and 1977.

Tore Brandin of Stahl Refrigeration also of Sweden told Galaxy in August 1976 they are now working on "large units (10 MW) with screw compressors to extend the range to 160°F.

All other organizations interviewed in all other countries were working at lower temperatures.

DOE has followed up on the SRM work. Subsequently, Galaxy's target was revised to the recovery and transmission and upgrading of low grade heat - (90°F to 140°F , input and is reported separately).

Over and over in Europe, interviewees stressed the combination of diesel or LP gas engines, using exhaust gas recuperators and exchangers which with heat pumps "would heat a house for 40% of conventional oil requirements." However, no one admitted to having solved the problem, or really done much more than "state it and study it."

In a follow-up investigation, Galaxy reported that a consortium had been formed of Ruhrgas, Volkswagen and Audi-NSU, for the purpose of developing a series of heat pumps to cover performance range of 12 to 400 kw, or about 1,000 to 350,000 kcal/h. The prime objectives were efficiency, simplicity, reliability and low capital cost. The development work was proportionately subsidized by the German Government.

Ruhrgas explained to Galaxy in 1978, that "as regard to efficiency, the work is based on the following principles:

1. Maintaining temperature differential as low as possible.
2. Provide speed regulation.

An internal combustion engine working with gas (because of environmental considerations)

is considered by the consortium to be the ideal prime mover. Heat in the exhaust gas can be recovered, thus keeping the temperature differential low and speed can be easily controlled. Conventional piston, as well as Wankel engines are being used.

The consortium has found a simple solution for capital cost. They use standard production line auto engines for double duty - as prime mover and as compressor. In the case for a four cylinder engine, two cylinders work as the prime mover and the other two as the heat pump compressor.

The consortium stated the development work has shown the reliability of the gas engine as good. An overhaul is only required after 10,000 hours of operation at full load.

This is calculated about 5 years of operation under normal conditions.

The consortium's assignment also includes the development of heat exchangers that will work well at temperatures below the freezing point.

While a combustion engine lends itself readily to speed controls, there is general agreement on the European Continent that a good variable speed drive was a prerequisite for maintaining a satisfactory coefficient of performance and for keeping a system under control. It is further generally agreed, that a rotary compressor is required for good performance.

The Gas Research Institute in U.S.A. announced a substantial program in gas activated heat pumps.

F. Small Steam Turbines
Below 100 HP:

This assignment specified a steam turbine of "low capital cost, high efficiency based on a substantial advance in technology."

No new technology has been identified.

In each country, the answer was "there is no market, and no effort is going into any new technology."

In Germany, there is some small effort.

One manufacturer who builds small turbines under 100 HP is Kuhnle, Kopp and Kausch near Mannheim in Germany. Its turbines are rated 60 HP, suitable for operation either at 600 psi and 800^oF, or 1850 psi and 970^oF.

Both are back pressure turbines, 60 psi back pressure. However, the efficiencies can only be classified as "rather poor".

After conferring with the Project Manager based on the reports submitted, further work was discontinued in 1978, clearing the way for further U.S. R&D.

G. Fuel Cells:

The assignment to Galaxy was made and re-defined by a successive number of ERDA/DOE Category Managers. These assignments from time to time covered advanced materials, molten carbonate, direct methanol, solid oxides, etc.

Galaxy reported the Netherlands' work on molten carbonate had been completed some years earlier.

The investigation of better material for separators which could withstand phosphoric acid and better electrolytes than phosphoric acid, led to Professor Ole Lindstrom of the Royal Swedish Academy.

Professor Lindstrom was familiar with the DOE sponsored work. Galaxy reported his work on a second generation fuel cell, based on a 200 KW substation with a standard 4 MW

cell fed by wood or peat to produce a hydrogen/
CO₂ reaction. As this approach had not been
developed by DOE, Professor Lindstrom's
papers on the subject were secured and trans-
mitted to DOE.

Professor Lindstrom's studies showed that
wood and biomass wastes were more efficiently
used in fuel cells than in biomass fired
thermal plants. However, DOE, at that time
gave priority to coal fired thermal plants
and Galaxy was not requested to follow-up
further.

In the papers furnished to DOE, Dr. Lindstrom
explained at length his scrubber system for
getting rid of sulphur and particularly CO₂.

The cells with acid electrolyte such as sul-
phuric or phosphoric acid can tolerate CO₂
which is vented with other gasses from the
cell. Cells with alkaline electrolyte cannot

tolerate CO₂. Professor Lindstrom prefers the alkaline system, using his scrubber based on lime which successfully gets the CO₂ down to 203 ppm at a cost of \$120 per kw installed.

He said that the Swedish system cost \$450 per kilowatt installed and reached about 45% efficiency using wood. He feels he is bettering the conventional system. He feels that CO₂ problem is best handled by dry methods with lime. He has designed a new scrubber and has a patent application on it. He felt that after he moved to the 4 or 5 megawatt size, his next steps will be 100 megawatts and then on to 200 to 300 megawatts. From this point, the discussion went on to catalyst and electrocatalyst and the best types of electrodes which were covered in the papers submitted.

As the priorities in the Power Systems Division changed with the creation of DOE in late 1977, Galaxy's assignment priority was shifted to the use of methane from coal beds as a fuel cell feedstock. Most investigations were in connection with the methane from coal beds assignment. No actual on site fuel cell use could be identified in Germany, the Low Countries, or the U.K., where methane from coal beds is extracted.

2. Heat Transfer & Thermodynamics:

This technology is basic to almost all of the other energy systems under the DOE program. Its importance is highlighted by the vast amounts of reject heat, which could do so much to improve energy efficiencies in the U.S. if economic heat exchangers can be applied to its recapture and uses.

At the beginning of this investigation, Galaxy found that seemingly little progress had been made in heat exchangers since the German work prior to World War II.

However, in the course of this contract, two or three major developments in the transfer of new technologies are reflected below.

A. Fluidized Bed Heat Transfer:

In brief, DOE was considering the development of a fluidized bed heat transfer system. Galaxy sent a senior staff member to confer with Fluidfire Ltd., who were operating under the Douglas Elliott patents. This company offered fluidized bed heat transfer units in a wide range of capacities. Galaxy forwarded the technical data to the DOE contractor for this field. The DOE program manager determined to test the device in U.S.A. under a DOE contract. It was shipped and installed in Hartford, Connecticut.

The tests have been completed. The performance was fairly well in line with the claims of the manufacturer, allowing for the difference of specific heat in the exhaust gases on which they were based, and the hot air used here. The full scale test however, did not indicate economic payoffs.

Galaxy has not been asked to follow-up with the manufacturer concerning the economies resulting from the sales and use of this device, which is, as of the time of this report, being built and sold in several countries.

B. Joint Technology Program on Heat Transfer
Via HTFS-HTRI-University of Maryland &
Oklahoma State University.

Following a preliminary Galaxy report and recommendations made in September 1976, a program was evolved to utilize the HTFS (a Division of the Harwell Laboratories in the U.K.) concept of linking governmental and industrial research, covering heat transfer and allied technologies in the U.K.

Mr. Geoffrey Hewitt of HTFS came to Washington for further discussions earlier this year. At these conferences, led by Dr. Carsey of Galaxy were: Mr. Perlsweig of ERDA/DOE; Drs. Toboric and Bell from Oklahoma State University; Dr. Marcello from the University of Maryland and Dr. Hewitt of HTFS.

After approval of the concept of the University of Maryland as the "linking pin" with HTFS, Mr. Perlsweig of ERDA/DOE visited Harwell late in May for further discussion.

This was followed by a visit to HTFS by Dr. Carsey which clarified the concept of HTFS and CONRT being linked through the University of Maryland with an American organization as part of HTFS's subscription network. This would eventually lead to HTFS-HTRI project and lateral U.S.A. - UK research programs in the heat exchangers/heat transfer area.

Galaxy recommended the primary objectives of the first project would be the development of research and development proposal which the University of Maryland and HTFS undertake a joint effort of the following fields:

- A. Heat Exchangers.
- B. Boundary layer problems.
- C. Fouling.
- D. Coverage of other energy related programs in the U.K.

Subsequently, to meet certain proprietary constraints ENSCIE, which was affiliated with the University of Maryland was created, and placed under contract by DOE.

The initial transfer of technology has begun with reciprocal visits between ENSCIE and HTFS.

As a result of this carefully designed program, Galaxy recommends:

1. Enhancement of Constructive communication and clearinghouse concepts within the industry nationally and internationally.
2. Careful selection of a few DOE-sponsored research and demonstration projects.
3. Initiation of projects which maximize the ability of cognizant DOE Officials to be apprised (within proprietary limits) of pertinent developments in the

heat transfer field. This needs to be addressed outside the network established through the IEA. (Although the IEA has an important political role to play in establishing an international posture for DOE, it is our opinion that its very political nature hampers its ability to be a sufficiently effective information clearinghouse).

4. The development of incentives to American industry to incorporate the significant energy saving concepts which are "on the shelf" in the heat transfer area. Tax incentives (or some other potentially viable methods) must be incorporated within the next few fiscal years.

This concept is developed in more detail in the reports of 1977 and 1978, and is recommended for more widespread use in other technical areas.

C. Pressure Wave Heat Exchanger:

Galaxy was requested to report on the Swiss Brown Boveri Company's development of a high efficiency gas energy exchanger. This had been named "Comprex" by Claude Seipple its developer in the 1960's.

The method was based on a direct fluid to fluid energy exchanger whereby the available energy expansion of hot combustion gas from a turbine or diesel is transferred directly to a colder gas by using a system of isentropic compression waves to avoid shock losses.

Specifically, Galaxy was requested to determine if Brown Boveri had developed a Comprex exchanger suitable for a topping cycle for a gas turbine of 40 megawatts.

After many discussions, Brown Boveri finally disclosed they had not developed a Comprex of the size desired, although they had developed Comprex for supercharging diesel engines for vehicle use. (See pages 66-69, Seventh Quarterly Report, September 16, 1978)

Brown Boveri estimated a cost of \$3 million annually and \$3 million for construction of a prototype.

Subsequently, DOE has let a contract to Mathematical Services Corporation for investigation and evaluation of this type of heat exchanger in U.S.A.

D. High Flux Heat Transfer Surface:

In late 1977, Galaxy was asked to supply a technical report on the actual field experience of the Japanese developed high flux heat transfer service called "Thermoexcel". (See pages 60-92 of the Fourth Quarterly Report, December 1977 for full report)

Subsequently, Galaxy's Japanese office arranged for the Chief Engineer of Hitachi Ltd. (Japan) to come to the U.S. for direct discussions with DOE experts in heat transfer, HTRI and other interested experts.

They found the 'Thermoexcel' technology to be a substantial advance in the art.

As a final step Hitachi Ltd. agreed to furnish a bundle of 'Thermoexcel' tubes to HTRI in California for test. HTRI will publish the results for consideration by design engineers in the U.S. power industry.

D. Determination of Sulphur Dewpoint in Diesel Stacks
Heat Exchangers for Waste Heat Recovery From Diesel Stacks

The Rankine Cycle work has been described earlier.

These two subjects are also closely allied with the general work on waste heat recovery.

Galaxy's ongoing assignments in this field extended from 1976 through 1978.

A review of all identifiable projects in Japan, the Middle East, Europe, Scandinavia and the U.K. failed to identify any advanced work on determination of sulphur dewpoint.

Following this negative report, DOE let a contract for this research in the U.S.

On the technologies for heat exchangers for waste heat recovery, positive reports were made.

In late 1977, Galaxy reported an improved boiler for waste heat recovery from diesel exhaust boilers by Thune-Eureka of Norway.

DOE's Heat Exchanger Expert, Michael Perlsweig raised several questions about the drawings and data. Galaxy arranged a meeting in Washington with Officers of Thune-Eureka. They explained the use of turbulators to cut the size of the recovery boilers by 50%. No commercial installation is yet available for inspection.

After a visit to the parent company factory in Sweden, Galaxy in 1977 recommended the Sunrod pin-tube diesel exhaust heat exchanger for more detailed examination by DOE.

Upon DOE's expression of interest, Galaxy arranged for inspection of Sunrod's installations on Norwegian ships visiting Los Angeles.

DOE then determined to subject the Sunrod exchanger to tests in connection with the sulphur dewpoint research project. Sunrod was requested to provide samples for test by an American Contractor to DOE, conducting the tests. When the Board of Directors of the parent company had agreed to the tests and found their product was to be turned over to a private American firm which they considered competitors in the field, they terminated their cooperation. The friendly intervention of the Swedish Embassy here and the American Embassy in Stockholm failed to change their decision. The matter stands at that point.

F. Plastic Heat Exchangers:

Development of plastic pipe heat exchangers has been led by Sweden, Italy and Germany.

The ongoing Swedish work at Studsvik in developing cross-linked polyethelyne liquid to air and liquid to liquid heat exchangers was reported in 1976-'77 and '78, and recommended for consideration by DOE.

By the latter part of this period, the R&D work had been completed and at DOE's request, Galaxy obtained offers on commercial quantities of the pipe for test in the U.S.A.

In Sweden the pipe is in use in hot water radiators in houses with liquid temperatures to 200°F, as well as commercial building fan driven heat exchangers, street snow removal heating, etc. Of course, a

major immediate use of plastic heat exchangers is in highly corrosive environments, such as the plating and galvanizing industry and the chemical industry. This conserves heat and avoids continuous ventilation.

In Denmark, plastic pipe liquid-to-earth heat exchangers are in use in heat pumps.

In Germany, plastic pipe is in use for liquid-to-earth waste heat utilization in speeding silviculture.

In Italy, a project using modular elements in a tube nest for plastic liquid-to-air heat exchangers in a Dry Cooling Tower.

Galaxy reported on the patent situation and the details of the assembly. Subsequently, Argonne National Laboratories is preparing a study for an R&D effort in this field.

Galaxy recommends follow-up in all the above plastic heat exchanger technologies.

3. Waste Heat Utilization, Cogeneration-
Planning and Analysis:

This assignment has been ongoing over 2-1/2 years since the inception of this work.

Investigations have been carried on in all countries specified in the contract.

As noted earlier in this report, most technologically advanced countries such as Japan, Germany, Scandinavia and the U.K. have up to this time, been short of domestically produced petroleum energy sources and are resultantly farmore active in waste heat utilization.

Sweden's standard of living is comparable to that of the U.S. Its climate is colder. However, its per capita consumption of energy is less than 70% of the U.S. The difference is largely due to better waste heat utilization, aided, of course, by better public transportation.

So many technologies and applications of waste heat utilization were reported that many have been referred to in other parts of this report (heat exchangers, diesel waste heat recovery, topping cycles, etc.) that only the remaining highlights can be covered in this section.

Therefore, in the interests of conservation of space, the subjects covered are:

- A. Long distance transmission of low grade heat.
- B. Heating transport system based on ammonia water solutions.
- C. Cryogenic waste utilization.
- D. Additional waste heat utilization Process.
- E. Recovery of heat from ferrosilicon furnaces.
- F. Reclaimed heat from fuel gases.
- G. Planning and Analysis.

A. Long Distance Transmission of
Low Grade Heat:

Basic to the U.S. utilization of waste heat, is the distance between the source and potential use, and the fact that huge quantities of heat between 140°F - 180°F are available.

Sweden and Germany have been leaders in the Free World in developing this technology (the Russian and other East Zone Countries are outside the scope of this contract).

The Swedish advanced R&D, under Peter Margen has been carefully studied by our field staff, and senior staff from Headquarters visited the laboratories in 1976 and '78.

In 1978 meetings were held in Washington with Dr. Margen, his professional staff, and DOE personnel. The advanced work on polyethelyne lined cement and plastic pipe,

glass fiber reinforced, as well as direct in-the-earth pre-insolated cross-linked polyethelyne pipe was fully discussed.

The Swedish experience covers heat recovery from fossil fuel thermal plants and was thoroughly covered in Galaxy's on site inspection reports, in technical papers, and in direct exchange of views between Swedish and DOE professional personnel.

In addition, Galaxy has provided quotations for certain sizes of cross-linked polyethelyne pipe from Swedish sources. As a result, DOE plans to test a substantial length of this pipe in service in the U.S. Galaxy has interested at least one American manufacturer in licensing the technology for production here.

The Swedish data shows almost 100% increase in energy recovery through use of back pres-

sure turbines, for district, commercial and residential heating in local areas.

The Swedish technicians are well advanced in studies for bringing the waste heat of Forsmark nuclear plant some 70 miles to Stockholm, and utilizing a heat pump at the discharge end to recover any remaining heat and reduce the temperature at the point of discharge. There is also a 50 mile 3 metropolitan area proposal in engineering stages on Sweden's West Coast.

The Federal Republic of Germany, using the same back pressure turbine heat recovery method from both fossil fuel and nuclear plants, is planning a network converting practically all major industrial population and employment centers.

The technical papers have been transmitted to DOE during the course of this study. The

page references and technical papers are too numerous to repeat in this summary and evaluation. They show an 8 to 1 tradeoff of electricity for heat in oil fired thermal plants and similar but reduced side results on total energy diesel plants. Forty mile transmissions of waste heat are now economically sound, and as mentioned, 70 mile transmissions are now on the boards.

Similar work in the Low Countries and in France have been reported to DOE.

Galaxy finds no technical barriers to transfer this energy efficient technology to the U.S. The advanced research has been reported and patent licenses are available.

Galaxy, therefore, recommends the goals of DOE in this field can best be attained by removal of institutional and legal barriers and provision of incentives for accelerated use here.

B. Heating Transport System Based On
Ammonia Water Solutions:

Galaxy reported (see pages 70-71, Seventh Quarterly Report, September 1978) the Erno-Raumfahrttechnik work in this field. It is still in the study and computer simulation stage and is not yet recommended as ready for transfer to the U.S.

C. Cryogenic Waste Utilization:

Early in this contract Galaxy proposed investigation of the use of cryogenic energy available at the proposed new LNG landing and gasification plants.

Galaxy reported the use of this cryogenic energy in Japan, Spain and France.

Near Washington is the first large scale LNG landing gasification plant. It uses incoming LNG as the heat source for gasification. Four miles away is a 1600 MW nuclear electric plant with huge amounts of reject heat, carefully passed through series of heat exchangers to reduce the outfall temperature to ambient Chesapeake Bay temperatures. With this large ΔT , somewhat less than 1 million horsepower appears to be going to waste. The infrastructure to transmit resultant generated electricity is already in place.

Galaxy recommended a pilot project for waste cryogenic and heat recovery at this location. ERDA/DOE sent a letter to each company, which brought the expected response of lack of interest. Due to successive reorganizations and mission changes, this matter still awaits follow-up.

As the siting of several proposed new large LNG plants should involve consideration of the use of the waste cryogenic energy either in food processing or other industrial use, or in generation of electrical energy, Galaxy recommends follow-up on this source, the technology for which is available for transfer.

D. Additional Waste Heat
Utilization Processes:

In connection with this section, it should be noted that the reports on such technologies as Rankine Cycles, Stirling Engines; Heat Pumps; Diesel Waste Heat Boilers; Compres Pressure Wave Exchangers, etc., are all part of waste heat utilization. They have been covered under "Heat Transfer".

E. Recovery of Heat From
Ferrosilicon Furnaces:

Thune Eureka of Norway has a process for heat/energy recovery from FCSI furnaces, making it possible to recover 20% of total electric consumption and to use the remaining heat after the turbine for plant heating and other industrial uses. Galaxy arranged a meeting between Program Manager Perlsweig and the Corporate Officers of Thune Eureka. This led to a request that Galaxy determine the capital cost per installed KW. For a 7000 KW plant, this was calculated at 900 per KW. Other savings in investment and operation of the baghouse result.

This appears a marginal development, but useful in some installations. Complete package installations are available for the U.S. Ferrosilicon industry.

F. Reclaiming Latent Heat in Fuel Gasses:

The ICCO condensation recuperator was developed by Gas de France and L'Industriel Chauffage, and installed at Quetigny. In response to further requests from DOE, Galaxy arranged for a DOE contractor to make on-site inspection of the larger installations in France.

Galaxy has not received reports on the action following these inspections.

G. Planning and Analysis:

Since all of the technologies reported above (plus others investigated and not reported because they proved not to be in advance of the state-of-the-art in U.S.A.) involved these factors, they are not reported separately.

4. Combustion, Alternative Fuels, Materials and Fabrication:

This also has been an ongoing assignment, beginning in 1976. The original assignment included IC Engines as well as furnaces, etc. As the mission of CONRT changed to PSD, the emphasis narrowed toward coal and coal product combustion.

Therefore, the early investigations of combustion for Stirling Engines, coal oil mixtures for diesel engines, etc., are indicated here only by reference to the Progress Reports on these subjects in 1976 and 1977.

Included are; Dr. Rolph Collin's work in Sweden on flat non-swirl blue flame burners, with a claimed 20-25% quota efficiency, better heat transfer, lower NOX, etc. Dr. Collin's work also included better furnace configuration. Also

included are Dr. Timnat's work in Israel on tunnel burners and scale free method of heating steel billets and Dr. Adler's work on high velocity burners; the fluidized bed work on the National Coal Board in the U.K.; the fluidized bed work in the Netherlands, etc.; the search for attaining 3500 degree temperatures in flame chambers for stationary gas turbines.

The research on direct combustion of oil shale in Israel has been reported in earlier years. Arrangements had been made for mining and forwarding to the U.S. substantial amounts of Israeli oil shale for direct combustion tests here. After a lapse of many months, Professor Y. Schacter of Bar-Ilan informed Galaxy in October 1978, that the material will be available in early 1979.

Combustion of Industrial Wastes:

The Power Systems Division requested a Worldwide sweep of this technology in the summer of 1978. (See pages 3-11 of Sixth Quarterly Report) The Seventh Quarterly Progress Report of September 1978 reviewed the state-of-the-art in Japan, the U.K., Scandinavia and Europe (see pages 2-64). The Japanese work on combustion of atatic polypropylene, was followed by preliminary data on some 20 plants in Germany, France, and Scandinavia.

As this Biennial Report goes to press, the Power Systems Division is studying the preliminary data in order to select those plants for further indepth investigation to be followed by on site inspection of the most significant plants by PSD Project Managers.

Gasification of Agricultural Wastes:

This area was specifically excluded from the Combustion of Industrial Wastes assignment. However, in late September, the Project Manager asked for another World-wide sweep to investigate gasification of agricultural, biomass and wood product wastes.

The initial effort was scheduled for completion by the end of calendar 1978, predicated upon further modification of this contract. Due to late action on the appropriation from DOE, this could not be accomplished, and work was suspended pending further action by DOE. Prior to suspension of work on this assignment, Galaxy had completed the survey of the state-of-the-art in U.S.A. as a basis for determining advanced work overseas; had instructed the overseas offices to begin work; and the

Galaxy-Tokyo Office had reported no significant advanced technologies available in Japan. The Australian Office reported their R&D will be performed in the U.S. under contract. In Germany, Volkswagen's work on gasification of wood wastes was noted; as was Volvo's and Motolas' work in Sweden.

Completion of this work is pending modification of the current contract.

Methane From Coal Beds:

This was given priority in mid 1977 and after reports from overseas, Galaxy sent a senior representative to France, Germany and the U.K. (See pages 92-103 of Fourth Quarterly Report of December 1977, plus technical papers).

In Northern France the gas is recovered, blended with coke oven gas, and the blended coke gas and 60% methane from mine drainage is distributed to Arros. They concentrate on post mining gas recovery, but are studying the USSR's pre-exploration program for greater gas recovery.

In Germany, Galaxy found that in spite of a negative report on methane recovery to a Congressional Committee visiting Essen, in Southern Germany, Saarberg Interplan is recovering substantial amounts of methane

and is currently doing very advanced pre-drainage work with hydraulic fracturing, negative pressure pumping resulting in 94 to 96% CH₄, 2% N₂, extracting up to 200 cubic meters of gas per ton of coal mineral; with a total of 443 million cubic meters gas fuel from all coal resources, and 159 million meters recovered for energy purposes.

The Saarberg people are familiar with the recovery work in Russia, China and throughout Europe and the U.S.

Saarberg indicated their willingness to send Dr. Swoboda to Washington in December 1977 to meet DOE for further technical discussions.

In view of Saarberg's experience in this field, Galaxy recommends DOE utilize this source of data on recovery of methane from coal beds.

Coal Oil Mixtures, Micron and
Sub-Micron Sized Coal:

In early 1978, Galaxy was asked to report on the state-of-the-art in this field in Japan (see pages 5-11, Fifth Quarterly Report dated March 1978).

A quick response indicated Japan was using a 1:1 coal oil ratio 75 μ sized pulverized coal; and considered that the optimum size. The report covered the entire Japanese program of milling the coal, transport, combustion and use. The proposed use is in steel and cement plants and power house boilers. The Japanese report the 75 μ size was selected to give the greatest flexibility of mixtures and the optimum combustion rate. No COM for diesel use is indicated in this program.

As the target date for completion of this R&D program in Japan is 1981, Galaxy recommends follow-up on this program as it develops, as considerable data will be available.

Coal Conversion:

Galaxy's assignment on coal conversion in mid 1977 was directed at Europe only. The work in France, Switzerland and the Low Countries was not impressive.

The synopsis of Galaxy's findings in Germany (see pages 109-117, Fourth Quarterly Report of December 1977) happened to be concerned with Secretary Schlesinger signing an agreement for U.S.-F.R.G. cooperation on R&D efforts in the field of coal technology. That agreement provides for the follow-up on this technology and Galaxy has no further recommendations.

Materials & Fabrication:

This category has primarily been covered under other sections of this report, such as the use of ceramics in coating of diesel pistons; cylinders and rings; heat recovery from ferrosilicon furnaces; improved materials for fuel cells; high temperature heat recuperators; topping cycles; the ceramic coatings and technology for application for gas turbine blades, etc., throughout the thousand plus pages of the progress reports. Repetition of this material here would be an unwarranted duplication.

However, not covered in other sections were the developments in the technology for producing high purity silicon nitride and silicon carbide and for fabricating parts. Therefore, Galaxy surveyed the world situation and centered in Japan as representing

the most concentrated overseas effort (see pages 97-123, Third Quarterly Report, September 1977).

The report covered the major Japanese R&D program aimed at production of commercial quantities of high purity silicon nitride and silicon carbide by 1981. It was Galaxy's conclusion that while there appears to be no breakthroughs, good mass production of high purity powders can be obtained within that time frame.

The attainment of moulded products of high strength is believed to depend more on the processing technology than on the powder itself. It appears that the sintering method may prove superior to hot pressure or CVD.

Galaxy recommends further follow-up of the Japanese program toward the 1981 completion date.

Controls & Process Efficiency:

The major effort in this field was directed toward more efficient industrial processes. Prior to the creation of DOE, and the reorganization of ERDA's CONRT Division into DOE's Power Systems Division, major program investigation and recommendations on overseas efficient agricultural/commercial applications were made.

In 1976 and 1977 Galaxy's reports and recommendations covered data on drip irrigation in Israel; UHT milk sterilization in Sweden and Switzerland; industrial bake ovens in Europe and the U.K.; hot deboning in the U.K. and Australia; gaseous sterilization of food; nitrogen fertilizer improvements; textile foam dying and hyper filtration of dyes; energy saving in alfalfa drying via the Pro-xan process in France; automatic coal fired

boilers; residential sized fluidized bed furnaces; direct combustion of wood residue fuels; pyrolysis and gasifier systems.

Many other technologies, such as the recovery of cryogenic energy from LNG gasification plants for example could well be in this category. Again, this has been handled elsewhere in this report.

The results of these overseas investigations were reported in detail in symposiums with the appropriate Project Managers in what is now the Division of Industrial Applications and Commercialization of the Assistant Secretary for Conservation and Solar Applications.

A substantial number of these technologies are now under study and some in substantial commercialization in the U.S.

Controls:

This aspect of Galaxy's assignment again cuts across many of the technologies previously reported.

However, the preliminary first phase assignment for investigation of the hierarchical computer control system developed by Nippon Steel Company in Japan (see pages 84-87, Seventh Quarterly Report of September 1978).

In accordance with the assignment, Galaxy's Tokyo Office held a series of discussions with Corporate Officers of Nippon Steel concerning their system. These discussions confirmed that Nippon Control System did indeed accomplish energy savings of 20% to 30%.

Thereafter, our Tokyo Office was successful in obtaining Nippon Steel's agreement on the basic points which were requested in the first phase of this project.

These points are:

1. Agreement in principle that Nippon Steel will license their KIIS computerized control technology to DOE or to U.S.A. steel firms.
2. Agreement to receive a DOE team, subject to an acceptable time schedule for preliminary discussions and demonstrations.

Galaxy's Tokyo office can develop and identify data on the savings of energy, labor and scrap under this system, as well as increases in productivity. Under an agreement of confidentiality, Galaxy can provide additional data considered confidential, proprietary and sensitive by Nippon Steel, but which DOE may use internally to reach a decision as to the next steps.

Galaxy has also advised that if as and when DOE has reached a decision, Galaxy is ready to negotiate a license with Nippon Steel for pertinent parts of the KIIS Hierarchical Control System.

Further work on this project awaits further contract with DOE.

APPENDIX

List of Progress Reports submitted by Galaxy which are incorporated in this report be reference. (Individual reports on individual technologies, delivered to individual DOE Project Managers are not included.)

September	1978
June	1978
December	1977
September	1977
June	1977
March	1977
December	1976
November	1976
September	1976
August	1976
July 27,	1976
July 6,	1976
June 28,	1976
June 8,	1976
April 26,	1976